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USSR

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PHYSICAL SCIENCES AND TECHNOLOGY
(FOUO 2/79)

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ELECTRONICS AND ELECTRICAL ENGINEERING

UDC 621.372.823

BIMETALLIC CIRCULAR WAVEGUIDES FOR RADIO RELAY LINE ROUTES

Moscow ELEKTROSVYAZ' in Russian No 9, Sep 78 pp 34-42

[Article by Yu. M. Isayenko, V. V. Malin, and A. P. Kokonin, submitted 3 Apr 1978]

[Text] Introduction. The growth of the carrying capacity of radio relay communication systems imposes heavier and heavier demands upon the quality of the waveguide plumbing.

In principle, it is possible to separate the vertical and horizontal parts in the plumbing. The vertical part is characterized by its considerable length (up to 120 m) and rectilinearity; the horizontal part is relatively short (up to 20 m) and, as a rule, has several elbows. Therefore, waveguides used in the vertical part must have sufficiently low linear ohmic losses. It is not necessary to bend waveguides (with the exception of the case of a special elbow). The waveguides of the horizontal part may have higher linear ohmic losses, but must tolerate sharp bends. Due to this, it is practical to use rigid circular waveguides in the vertical part of the plumbing, and flexible elliptical waveguides in the horizontal part.

Ohmic losses in a circular waveguide working on a fundamental wave H_{11} can be reduced by increasing its diameter. However, in this case, in a real waveguide having random discontinuities the excitation of parasitic waves growth and the parallel flow increases. As a result, the total (fluctuation and transition) noise caused by the waveguide plumbing could even increase for waveguides with enlarged diameters. The existing copper circular waveguides (CW) 70 mm in diameter have insufficiently high electrodynamic parameters and do not make it possible to realize a waveguide plumbing with a high capacity due to the low precision of the inner channel of the waveguide. In this connection, it became necessary to develop new waveguides with considerably higher parameters than those of copper waveguides.

Individual problems of the development of new bimetallic waveguides (BMW) are discussed in [1,2]. This article gives the results of a complex study of bimetallic waveguides and their geometric and electrodynamic parameters.

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Design Features. The bimetallic waveguide section is a steel carrier pipe with a thin layer of copper 0.3 mm thick plated on its inner surface. The copper layer and the steel substrate are connected permanently. The inner diameter of the BMW is 70± 0.05 mm, the thickness of the waveguide wall is 4 mm, and the length of the section is 5 m. The outer surfaces of the ends of the sections have fitting bands and circular grooves machined on a turning lathe (Figure 1). In order to ensure anticorrosive protection and stable highly conducting contact, the ends of the sections and a part of the outer surface, including the grooves, are covered with a layer of nickel.

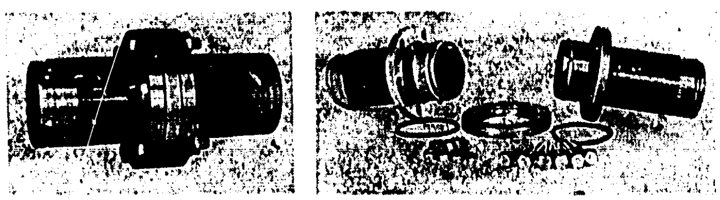

Figure 1

When BMW are connected, flanges are placed on their ends, elastic split rings are inserted into the grooves, and rubber sealing rings are installed. The centering is done with a sleeve. The butt joint is tightened with bolts. In order to obtain high-quality BMW, a special multistage production technique was developed[1].

Main Advantages of BMW over CW: 1) a substantial saving in copper -- 90-95%, for example, for an RRL [radio relay line] of 1000 km -- over 23 tons; 2) the possibility of using rigid suspenders, which are simpler than the spring-type suspenders, due to the closeness of the linear expansion coefficient of the BMW and the radio relay mast; 3) a considerably higher strength and the rigidity, which considerably reduces the possibility of damaging waveguides accidentally in the process of their transportation, storage, installation, and operation; 4) completely dismountable structure of the butt joints which ensures a greater degree of compactness and has 4-6 times greater tensile strength; 5) a substantially higher real precision of the inner channel.

Electrical Parameters. The ohmic losses of BMW are practically analogous to those of CW. According to the data of article [2], the losses in the frequency range of 3.4-3.9 GHz do not exceed 1.8 dB in a route length of 100 m.

Excitation Level of Reflected Wave H_{11}. The main sources of the excitation of the reflected wave are the steps at the place of junction and the pulsation of the diameter of the inner channel of the waveguide. As analysis has shown, the second source can be disregarded in comparison with the first one, therefore, joints alone are examined below.

1 The production technique was developed under the direction of A. A. Shevchenko and M. B. Rogov.

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The theoretical evaluation of the reflected wave level was done by formulas obtained for a waveguide 70 mm in diameter from general relations for calculating joints given in [3]:

$$\left.\begin{array}{c} \overline{W_{11}}=3{,}24\cdot 10^{-2}\dfrac{\overline{\delta_0^2}}{a^2}+0{,}58\,\dfrac{\overline{\delta_2^2}}{a^2}, \\ f=3{,}4\ \text{ГГц GHz} \\ \overline{W_{11}}=0{,}4\cdot 10^{-2}\dfrac{\overline{\delta_0^2}}{a^2}+0{,}29\,\dfrac{\overline{\delta_2^2}}{a^2}, \\ f=3{,}9\ \text{ГГц, GHz} \end{array}\right\} \quad (1)$$

where $\overline{W_{11}}$ is the mean value of the energy of the reflected wave from one joint; $\overline{\delta_0^2}, \overline{\delta_2^2}$ are the mean values of the squares of the zero and second harmonics of the Fourier series of function $\delta(\varphi)$ which characterizes the step at the place of junction.

The values of $\overline{\delta_0^2}$ and $\overline{\delta_2^2}$ were determined by the results of measurement of the diameter and ellipticity of the inner channels of large number of waveguides. The histogram of Figure 2 shows the results of measurements of the deviations of the average (over the cross section) diameter D from its rated value. The measurements were conducted on 23 sections of a waveguide every 100 mm along its axis. The mean value of the diameter D for this group was 70.01 mm, and the root-mean-square value of the deviation of the diameter from its mean value was 0.015 mm. Hence

$$\sqrt{\overline{\delta_0^2}}=\sqrt{\overline{(D-\overline{D})^2}/2}=0{,}011\ \text{мм}.$$

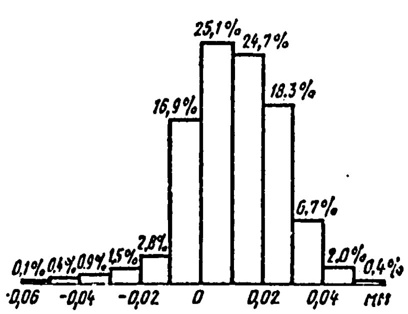

Figure 2

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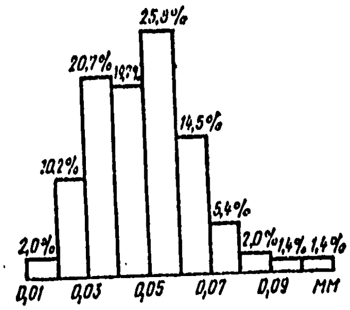

Figure 3

In order to find $\overline{\delta_2^2}$, we used measurements of the ellipticity Э only of the ends of the waveguides because, due to additional machining, they have a somewhat greater ellipticity than the inner channel of the waveguide. The results of the measurement of Э of 300 ends of waveguides are shown in a histogram of Figure 3. According to these data

$$\sqrt{\overline{Э^2}} = \sqrt{\overline{(D_{\text{макс}} - D_{\text{мин}})^2}} = 0{,}05 \text{ мм}$$

$$\text{max} \qquad \text{min}$$

and, accordingly,

$$\sqrt{\overline{\delta_2^2}} = \sqrt{\overline{Э^2}/8} = 0{,}017 \text{ мм.}$$

For the found values of $\overline{\delta_0^2}$ and $\overline{\delta_2^2}$, in accordance with (1), we obtain:

$$\overline{W_{11}} = 0{,}14 \cdot 10^{-6} (-69 \text{ дБ}), \text{ dB}$$
$$f = 3{,}4 \text{ ГГц; GHz}$$
$$\overline{W_{11}} = 0{,}69 \cdot 10^{-7} (-72 \text{ дБ}), \text{ dB}$$
$$f = 3{,}9 \text{ ГГц.}$$

The reflections of the wave H_{11} were determined also experimentally with the aid of a pulsed reflectometer IR-4 which made it possible to isolate the reflection from individual joints. The measurements were carried out in the waveguide plumbing installed at one of the operating RRL. Reflections from approximately 220 joints were determined and analyzed. The averaged value of the reflected wave energy was very small $\overline{W_{11}} = 4.9 \cdot 10^{-7}$ (-63 dB). Considering the possible individual inaccuracies in the assembling of the waveguides, it is possible to consider that the agreement between the measured and calculated (by the measured geometrical parameters) reflection coefficients was good. Analogous electrical measurements of butt joints of CW

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were also conducted. They showed that the amplitude of the reflected wave in them was, on the average, 3-4 times greater than in BMW.

Excitation Level of Extraneous Wave E_{01}. Waves of various types can be excited on waveguide discontinuities. In the frequency range of 3.4-3.9 GHz which is being examined, only the E_{01} wave among the extraneous waves in a waveguide 70 mm in diameter can propagate. The source of the excitation of the E_{01} wave in the plumbing is the nonrectilinearity of the real axis of the waveguides, as well as the steps and fractures in the places of their junction. The evaluation of the level of the E_{01} wave excited on these discontinuities is given below.

The axis of a waveguide has, as a rule, a spatial bend, however, only the projection of the bend onto the plane determined by the highest value of the component E_r of the wave H_{11} participates in the excitation of the wave E_{01}. As was shown in [3], the amplitude A_{01} of the wave E_{01} at the output of a section of length L is defined by the formula

$$A_{01}(L) = Q\int_0^L \varkappa(z)\, e^{-i(\beta_{11}-\beta_{01})z}\, dz, \tag{2}$$

where $\varkappa(z)$ is the curvature of the projection of the axis onto the abovementioned plane; β_{01} and β_{11} are the phase constants of the waves E_{01} and H_{11} respectively. The values of the fundamental values in (2) for two frequencies are shown in Table 1.

Table 1

f, ГГц GHz	$\beta_{11}-\beta_{01}$, 1/см	Q
3,4	0,2929	1,060
3,9	0,1832	1,169

In formula (2), the amplitude is normalized in such a way that its square modulus is equal to energy. The mean value of energy at the output of the plumbing consisting of n sections arranged arbitrarily in relation to one another

$$\overline{W} = \overline{|A_{01}(nL)|^2} = n\,\overline{|A_{01}(L)|^2}. \tag{3}$$

The return E_{01} wave is not considered here, because its amplitude is substantially smaller than the amplitude of the direct E_{01} wave.

The function $\varkappa(z)$ necessary for calculations was determined experimentally by means of measurements with the aid of devices specially created for this purpose. The results of the calculations for 90 waveguide sections (over 15,000 measurements of the axis curvature) conducted on an electronic computer in accordance with (3) are shown in Figure 4. The curves in Figure 4

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were plotted in the following manner. Out of the 90 calculated values for each frequency of the 3.4-3.9 GHz range, we selected the highest and the lowest values which were used in plotting the curves. It can be seen from the curves that the excitation levels of the E_{01} wave are very low and do not exceed -53 dB.

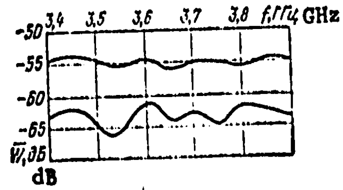

Figure 4

Measurements of a batch of waveguides manufactured at a different time yielded similar results, which indicates a sufficiently good stability of the developed technique.

The average level of the E_{01} wave at the output of the plumbing consisting n sections determined by formula (3) for n=10 (L=50 m) is -47 and -48 dB respectively for the frequencies of 3.4 and 3.9 GHz, and for n=20 (L=100 m) is -44 and -45 dB for the same values of frequencies.

Let us use the relations given in [3] for calculating the excitation of the E_{01} wave at the joints. These relations are given in Table 2 for the average (for the set of joints) values of the energy of the direct $\overline{W_{01}^{+}}$ and return $\overline{W_{01}^{-}}$ waves E_{01}, where $\overline{\delta_1^2}$ is the mean value of the square amplitude of the first harmonic in the Fourier expansion of the step $\delta(\varphi)$; $\overline{\theta^2}$ is the mean value of the square angle of fracture of the axes at the places of junction. The data of Table 2 correspond to one joint. For a plumbing consisting of n joints, the numerical values of the coefficients must be multiplied by n.

Table 2

f, GHz	$\overline{W_{01}^{+}}$	$\overline{W_{01}^{-}}$	$\overline{W_{01}^{+}}$	$\overline{W_{01}^{-}}$
3,4	$1,18\,\frac{\overline{\delta_1^2}}{a^2}$	$1,18\,\frac{\overline{\delta_1^2}}{a^2}$	$1,12\,\overline{\theta^2}$	$0,216\,\overline{\theta^2}$
3,9	$0,51\,\frac{\overline{\delta_1^2}}{a^2}$	$0,51\,\frac{\overline{\delta_1^2}}{a^2}$	$1,23\,\overline{\theta^2}$	$0,036\,\overline{\theta^2}$

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The value of $\overline{\delta_i^2}$ was determined by the results of the geometric control of the value of eccentricity of the outer diameter of the neck and the inner diameter of the waveguide and the value of the gap between the neck and the inner diameter of the centering sleeve

$$\left(\sqrt{\overline{\delta_i^2}}=0{,}03 \text{ мм}\right).$$

The value of $\overline{\theta^2}$ is connected with the nonperpendicularity of the end plane of the waveguide in relation to its axis. Analysis of 400 ends of waveguides yielded the value of $\sqrt{\overline{\theta^2}}=0{,}0008$ radian. According to these data, we obtain the following for one joint:

$$\overline{W_{01}^{+}}=0{,}69 \cdot 10^{-5}(-51\,\text{dB});\ \overline{W_{01}^{-}}=0{,}63 \cdot 10^{-5}(-52\,\text{dB}) \text{ at } f=3{,}4\,\text{GHz}\ \overline{W_{01}^{+}}=3{,}45 \cdot 10^{-6}(-55\,\text{dB});\ \overline{W_{01}^{-}}=2{,}68 \cdot 10^{-6}(-56\,\text{dB}) \text{ at } f=3{,}9\,\text{GHz}$$

Thus, the average accumulated level of excitation of the E_{01} wave (from bends of the sections and from the joints) in a 50 m long channel is evaluated by magnitudes of -41 and -45 dB for the freqeuncies of 3.4 and 3.9 GHz, respectively; and in a 100 m long channel, -38 and -42 dB for the same frequency values.

Excitation Level of a Cross-Polarized Wave (CPW). The main source of excitation for a CPW, i.e., a wave with polarization perpendicular in relation to the fundamental wave, is the presence of even a small ellipticity of the cross section. The excitation of the CPW causes elliptic polarization of the H_{11} wave at the output of the channel.

The CPW level was evaluated both theoretically and experimentally. Theoretical evaluation was carried out for the purpose of establishing the connection between the CPW level and the value of the average ellipticity of the waveguides, which is necessary for substantiating the precision requirements for their manufacturing (with respect to ellipticity).

Let us assume that the plumbing is assembled arbitrarily, i.e., without matching the sections with respect to one another and the entire channel in relation to the polarization plane of the H_{11} wave. Then, in order to solve the problem of the permissible value of ellipticity, it is sufficient to examine the problem of a channel with ellipticity constant with respect to its

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value and direction. Preliminary analysis has shown that it is in this case that the CPW level will be the highest.

First, let us mention that the degree of the excitation of a CPW can be evaluated by two methods: either by the ratio of the axes of the polarization ellipse of the elliptically polarized wave H_{11} at the output of the channel, or by the amplitude of the H_{11} wave at the output of the channel polarized perpendicularly to the direction of polarization of the H_{11} wave at the input of the channel. For the bimetallic waveguides discussed in this article, due to their small ellipticity, the direction of polarization of the fundamental H_{11} wave at the input is close to the direction of the major axis of the polarization ellipse at the output of the channel, i.e., the difference between the two above-mentioned methods can be disregarded. Hereafter we shall use the second method, which is simpler.

Let us use $A^{\perp}$ to designate the relative (in relation to the amplitude of the wave H_{11} at the channel input) amplitude of the wave H_{11} at the channel output polarized perpendicularly to the polarization of the wave H_{11} at the input, and, for short, refer to $A^{\perp}$ as the CPW amplitude. Then, it is possible to obtain the following expression for $A^{\perp}$:

$$A^{\perp}=\left|\sin 2\theta_1 \sin \frac{\Delta\beta z}{2}\right|, \tag{4}$$

where θ_1 is the angle between the major axis of the ellipse of the cross section and the direction of polarization of the wave H_{11}; z is the length of the waveguide; $\Delta\beta$ is the difference of the coefficients of the phases of waves polarized along the major and minor axes of the cross section ellipse. If $Э$ is the difference of the axes of the ellipse, then, as it is shown in [3], $\Delta\beta=1{,}557Э/\beta_0 a^3$,

where $\beta_0=\sqrt{k^2-\mu_{11}^2/a^2}$, a is the radius of the waveguide, $\mu_{11}=1{,}841...$, $k=2\pi/\lambda$,

$Э = D_{max}-D_{min}$.

At worst, when $\theta_1 = \pi/4$, from (4) $A^{\perp}_{max}=\left|\sin \frac{\Delta\beta z}{2}\right|$ or, due to the smallness of the magnitude $\Delta\beta z/2$,

$$A^{\perp}_{max}=|\Delta\beta\, z/2|. \tag{5}$$

Thus, we have for the CPW level:

$$A^{\perp}_{max}=20\lg|\Delta\beta\, z/2|, \text{ dB} \tag{6}$$

It follows from formulas (6) that the permissible value of the CPW level (not over -25 dB) in a 100 m long channel is ensured at $Э \leq 0.0015$ mm.

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The permissible ellipticity being so small, the fabrication of waveguides becomes unrealistic. Thus, it is practically impossible to make waveguides which would ensure high parameters with respect to the cross-polarization of the channel without any matching. The only way out of this situation is to introduce some tuning of the channel. The matching of individual sections to one another is a very laborious operation. Therefore, it was suggested to tune the channel assembled arbitrarily by rotating it in relation to the exciter.

If the entire channel had a constant and nonrotating ellipticity, then, as it follows from (4), at $\theta_1 = 0$ or $\pi/2$, the amplitude $A^{\perp}$ changes to zero. When the direction of ellipticity is not constant, the amplitude $A^{\perp}$ is not equal to zero, however, as it will be shown later, it decreases substantially. First, let us examine a model of a channel consisting of two identical parts ($z/2$ long) with constant ellipticity, but turned in relations to one another at an angle of θ_2. If in this case θ_1 is the angle between the direction of polarization of the H_{11} wave and the direction of the major axis of the ellipse of the input waveguide, then the amplitude $A^{\perp}$ at the channel output [4] is

$$A^{\perp}=\sqrt{\left[\sin\theta_2\cos\theta_2\left(1-\cos\frac{\Delta\beta z}{2}\right)\right]^2+\left[\cos\theta_2\sin(2\theta_1+\theta_2)\sin\frac{\Delta\beta z}{2}\right]^2}.$$

When the entire channel turns, i.e., the angle θ_1 changes, the minimal value of $A^{\perp}$ will be

$$\min A^{\perp}=\left|\sin 2\theta_2\,\sin^2\frac{\Delta\beta z}{4}\right|. \qquad (7)$$

This minimum has the second order with respect to the small value of $\Delta\beta z$, and zero will be only in a special case, at $\theta_2 = \pi/2$. There is no first-order term with respect to $\Delta\beta z$ even in more general cases when the channel consists of an arbitrary number of parts with constant ellipticity or of waveguides with variable ellipticity.

Let us now examine a channel consisting of real waveguides whose ellipticity, as measurements showed, is variable both with respect to its value and direction. First, let us establish the connection between the value of $A^{\perp}$ and the value of average ellipticity for each section. From the general relations given in [3], it is possible to obtain the following formula in the first order with respect to $\Delta\beta$:

$$A^{\perp}=\frac{1}{2}\left|\int_0^L\Delta\beta\sin 2[\Phi(z)+\theta_1]\,dz\right|, \qquad (8)$$

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where Φ (z) is the angle of rotation of the ellipse of the cross section along the waveguide in relation to the position of the ellipse at the waveguide input; θ_1 is the angle of the input position of the ellipse of the cross section in relation to the polarization of the wave H_{11} at the input.

In order to carry out calculations by (8), it is necessary to know the difference of the axes and the angular position of the ellipse along the axis of the waveguide. These data were obtained by means of measurements with a special probe pulled through the inner channel of the waveguide. Then, θ_1-maximum values of the CPW level were calculated for individual frequencies. The results of computations for ten waveguides selected at random from a batch are as follows: the mean ellipticity $\bar{\mathrm{Э}}$ varies from section to section within the limits of 0.015-0.060 mm, maximum (with respect to the angle θ_1 and with respect to frequency) values of the CPW level vary within the limits of -53 dB to -25 dB. The obtained results are described with a sufficient degree of accuracy by the relation $\max\limits_{\theta_1, f} A^{\perp} \approx 0{,}8\bar{\mathrm{Э}}$. If the waveguide had a constant ellipticity, then, as follows from (5),

$$\max_{\theta_1, f} A^{\perp} \approx 1{,}64\mathrm{Э}.$$

Thus, a waveguide with variable ellipticity is equivalent to a waveguide with constant ellipticity equal to one-half of mean ellipticity $\bar{\mathrm{Э}}$. This makes it possible to replace a real channel of sections with variable ellipticity with a channel of waveguides with constant ellipticity. Analysis has shown that the worst case for an equivalent channel will be that when one-half of the pipes in the channel have identical position of the ellipses and are turned at the angle $\theta_2 = \pi/4$ in relation to the other half of the pipes in which the position of the ellipses is also identical. Then, proceeding from (7), at

$$\min_{\theta_1} A^{\perp} = (\Delta\beta z/4)^2. \tag{9}$$

Hence, for z = 100 m, f = 3.4 GHz and the CPW level $\leqslant$ -25 dB, we obtain the permissible value of $\mathrm{Э} \leqslant$ 0.0125 mm. Allowing for the relation between the constant and variable ellipticities, $\bar{\mathrm{Э}} \leqslant$ 0.025 mm. As is shown by the analysis of the results of measurements, the distribution of the ellipticity values is close to the symmetric form, therefore, the final permissible ellipticity value $\mathrm{Э}_{max} \leqslant$ 0.05 mm.

The obtained value of the allowance for ellipticity corresponds to the worst position of the sections in the channel. But, since their arrangement in relation to one another is accidental, we evaluated the probability P of exceeding the prescribed value of the CPW level when the position of the channel as a whole in relation to the exciter is optimal [4]. The results of the

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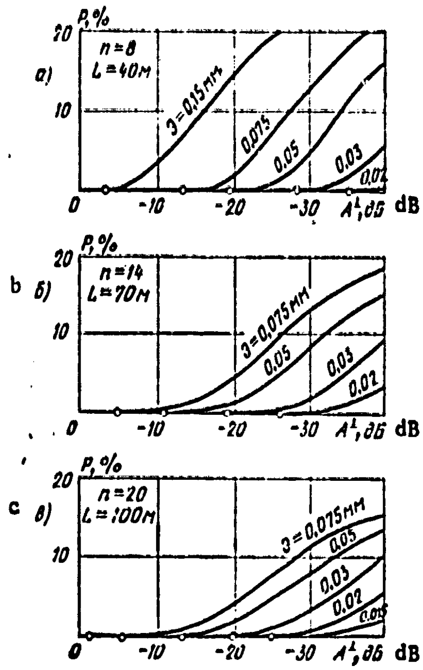

Figure 5

computations are shown by the curves in Figure 5. As a example, let us examine a 75 m-long channel with the ellipticity Э = 0.018 mm. In accordance with (9), its worst CPW level is -25 dB. However, according to Figure 5b, the probability of exceeding the CPW level value of -35 dB, i.e., location of the CPW level within the limits of -(25-35) dB, constitutes only 0.6%.

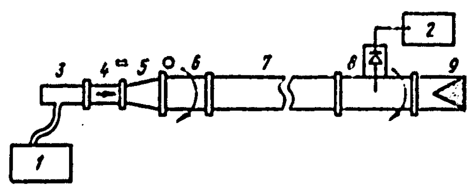

Figure 6

Experimental studies were conducted both on individual sections and on complete channels. The diagram of measurements is shown in Figure 6 which has the following designations: 1 -- microwave measuring oscillators; 2 -- indicator; 3 -- coaxial-to-waveguide transducer; 4 -- ferrite isolator; 5 --

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transformer of the wave H_{10} of a rectangular waveguide into the wave H_{11} of a circular waveguide; 6 -- swivel union; 7 -- circular waveguide Ø70 mm which is being measured; 8 -- rotating probe; 9 -- matched load. Comparison of the measured values of the CPW level for the same ten sections for which it was determined by computations showed that correlation between them was sufficiently good.

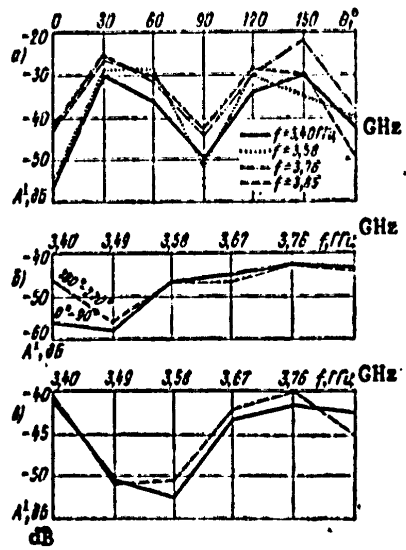

Figure 7

The results of the experimental studies of waveguide channels assembled without matching the sections are shown in Figure 7: a -- the dependence of the CPW level of a 35 m-long channel on the angle of inclination θ_1. As can be seen from the figure, the worst value of the CPW level is -22 dB, and the best value is -42 dB; b -- the dependence of the CPW level for one of the "good" positions of the exciter in relation to the channel. The CPW level for all frequencies being examined is not over -42 dB. The solid curve corresponds to the first position of the minimum of the electrical field being measured around the periphery, and the broken curve corresponds to the second minimum. The fact that the curves do not quite coincide could be due to the presence of the E_{01} wave in the aggregate field.

Figure 7c shows the frequency characteristic of a waveguide channel 75 m long. The exciter of the H_{11} wave is turned to the optimal position, and the CPW level (solid curve) does not exceed -42 dB. The turn of the polarization plane of the working wave at the output of the channel in relation

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to polarization at the input did not exceed 1.5 degrees. The broken curve is plotted according to the data of measurement conducted two months later. It shows a good stability of the parameters with time. Very high results were also obtained in measuring other channels. Comparison of the obtained results with an example of computations (Э = 0.018 mm) shows that the measurements correspond to the theoretical evaluations.

On the basis of the conducted theoretical and experimental studies, a new method of assembling waveguide channels (in their linear parts) was proposed. Sections are assembled in an arbitrary manner without any matching with one another. Then, the optimal position of the exciter in relation to the channel is determined. The determined mutual position of the sections and the exciter is marked. After disassembling and transporting to the installation site, the elements of the channel are assembled in the order marked. By using This assembling method in combination with high-precision BMW, it is possible practically to ensure a CPW level of not worse than -(35-40) dB of the linear part of the channel in the entire 3.4-3.9 GHz range. With the same assembling method, the CPW level for a channel with CW is by 5-10 dB lower in the same frequency range.

In accordance with the proposed method, it is not necessary to tune individual sections by the angle of rotation, which makes the assembling much less laborious.

Studies on long (up to 120 m) antenna-waveguide channels (AWCh) with the use of BMW with respect to the introduced noise have shown that a carrying capacity of over 1000 TCh [audio frequency] channels can be achieved in multichannel systems with such channels (for example, in the system "Rassvet-2"). Moreover, among the elements of the channel, a long waveguide introduces a small percentage of noise.

Conclusions. 1. The high-precision BMW which have been developed, put into production, and introduced on main communication lines satisfy the requirements imposed on waveguides used in the AWCh of modern multichannel (about 1000) radio relay systems with respect to all parameters.

2. With respect to the geometrical parameters, BMW meet the requirements imposed by the IEC [International Electrotechnical Commission]. For example, the allowance for the BMW diameter is $\pm$0.05 mm, while in accordance with the IEC standards [5] it is $\pm$0.07 mm.

3. The average measured amplitude of the reflected wave H_{11} from a butt joint is approximately 0.07% for BMW.

4. The proposed new method of assembling waveguides is less laborious and ensures high parameters of the assembled channel. The level of the cross-polarized wave in a 100 m channel does not exceed -(35-40) dB.

5. Methods were developed for calculating the main electrical parameter of circular waveguides by known geometrical parameters.

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GEOPHYSICS, ASTRONOMY AND SPACE

STUDYING THE BOTTOM OF LAKE BAYKAL BY USING SUBMERSIBLES

Moscow PRIRODA in Russian No 10, 1978 pp 58-69

[Article by A.S. Monin, corresponding member of the USSR Academy of Sciences and director of the Institute of Oceanology imeni P.P. Shirshov of the USSR Academy of Sciences, and Ye. G. Mirlin, candidate of geological-minerological Sciences and laboratory head of the Institute of Oceanology imeni P.P. Shirshov of the USSR Academy of Sciences]

[Text] Lake Baykal -- A continental Rift

A new device -- manned submersibles -- appeared comparatively recently in the arsenal of ocean investigators, by means of which the geologist can finally see with his own eyes the bottom relief and can check concepts about it gained by geophysical methods. Complex use of diverse hardware, beginning with echo sounding and ending in deepwater drilling, permits one to obtain extensive data on the most interesting regions of the bottom of the world ocean and to check numerous hypotheses of their origin.

In 1976, by order of the USSR Academy of Sciences, two "Pisces" manned submersibles (Pisces -- the constellation and sign of the zodiac), designed for complex investigations of the ocean bottom and of its water mass, were constructed in Canada. It was decided to conduct the first investigations with these vehicles in Lake Baykal, since Baykal is a continental rift. This is what the large linear structures of the earth's crust, having the shape of extended narrow troughs, are called.

Interest in rifts has increased especially after discovery of a global system of mid-ocean ridges in the 1950's the axial part of which are cut by deep longitudinal troughs. A belt of seismic activity extends along them and the most intensive anomalies of the geothermal heat flux, gravitational and magnetic field are confined to them. All these are signs of active tectonic processes. According to the ideas of the new global tectonics, the new oceanic earth's crust is formed in the axial part of the mid-ocean ridges, which then separates from the ridge axis at rates of 2-10 cm/year. This separation of the ocean bottom is part of the large-scale mutual movement of the rigid

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Yevgeniy Gilel'yevich Mirlin, candidate of geological-mineralogical sciences and laboratory head of the Institute of Oceanology imeni P. P. Shirshov of the USSR Academy of Sciences. He is involved in the geophysics and tectonics of the ocean bottom and magnetic anomalies of the ocean. In 1977, he headed the Baykal Complex Geophysical Expedition

lithospheric plates which include continental and oceanic surfaces in approximately identical measure. The plates are separated by relatively narrow belts where a large part of the mechanical energy of our planet is released. Interaction of the lithospheric plates and the processes occurring on their boundaries determine the geological face of the earth. Therefore, study of the active tectonic belts is one of the main trends of both international scientific projects and of national programs.

The geophysical fields and the morphology of oceanic troughs located along the axes of the mid-ocean ridges are similar to corresponding characteristics

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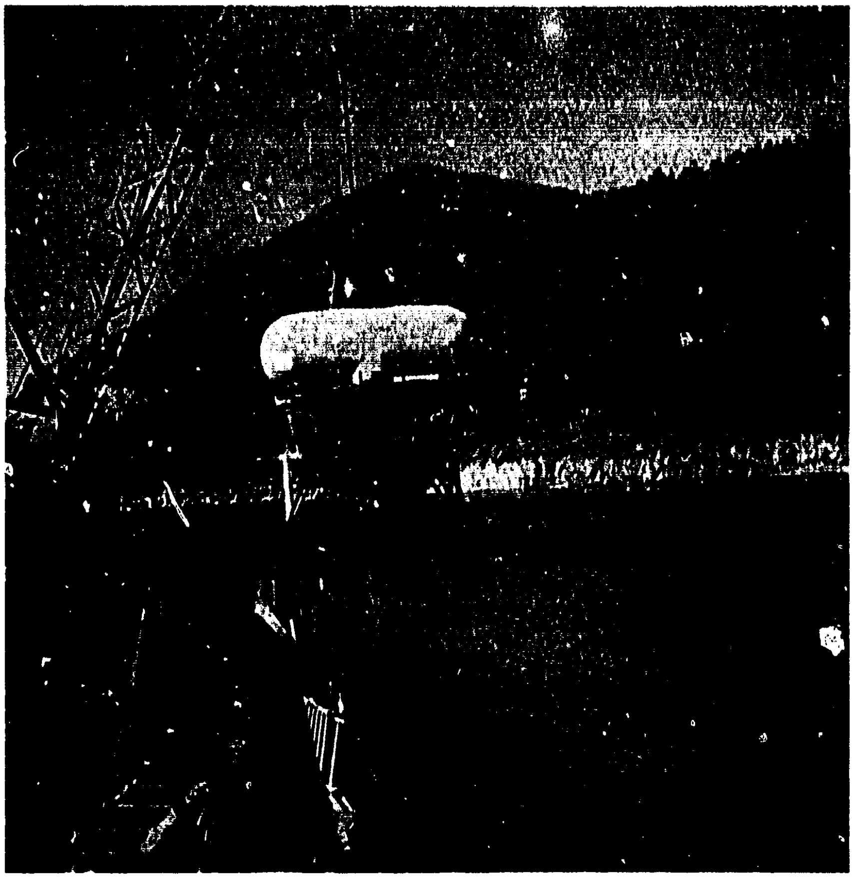

Launching of "Pisces" Vehicle

of the rift troughs of continents. Thus, for example, our only actively developing Baykal rift zone consists of a system of linear depressions with a total length of 2,500 km. The rift structures extend from northwestern Mongolia through the mountain edifices of Eastern Siberia to southern Yakutiya, forming an S-shaped curved arc of general northeasterly strike. The main one of these depressions has a length of approximately 700 km with a width of 30-50 km and maximum depth of 1,600 m. It is filled with water and is known as Lake Baykal -- the deepest freshwater reservoir of our planet. This entire belt is seismic and is characterized by very contrasting geophysical anomalies. These facts permit one to draw an analogy between the Baykal rift zone and the boundary regions of the lithospheric plates where the new oceanic crust is formed. To what degree is this analogy valid? What is the similarity and what is the difference of the mechanism of formation of the Baykal continental rift and the troughs in the oceanic parts of the mid-ocean ridges? Answers to these questions would help one to

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understand the history of the lake's formation and also a number of essentially important aspects of global tectonics.

The fact that Lake Baykal is a water-filled rift permits one to approach investigation of its structure by using methods for study of the ocean bottom. In other words, the entire complex of marine geophysical methods can be used to study Lake Baykal and observations can be carried out from submersibles for detailed investigation of the most interesting regions. These are the main concepts which were the basis for the program of study of Lake Baykal using oceanographic equipment, implemented in the summer of 1977 by the Institute of Oceanology imeni P. P. Shirshov and a group of institutes of the Siberian Department of the USSR Academy of Sciences.

The "Pisces" Submersibles

One can work in the seas and oceans up to depths of 2 km in "Pisces" submersibles. The crew of the vehicle consists of three persons -- two pilots and one scientist-observer. Each submersion usually lasts for not more than 8 hours, but the life-support system permits the crew to remain in the vehicle for 3 days. The weight of the vehicle is 10 tons and its horizontal speed is 2 knots.

The "Pisces-VII" and "Pisces-XI" vehicles were used during operations in Lake Baykal. They were constructed for working in sea water and, therefore, their use in the fresh water of Lake Baykal created a number of difficulties caused by the difference in the densities of sea and fresh water: part of the equipment had to be removed from each vehicle because of a reduction of buoyancy.

An important advantage of vehicles of this design is their high maneuverability. Each "Pisces" vehicle has a ballast-trim system which permits one to regulate the rate of descent and ascent and to provide suspension of the vehicle at any depth and movement of it at the western horizon. The vehicles are equipped with reversible electric motors which permit one to make maneuvers in the water mass and to move horizontally along a given course. All these qualities of the vehicles were very valuable during operations in Lake Baykal, where steep slopes and almost vertical walls were investigated.

The "Pisces" scientific-apparatus complex includes a "mechanical arm" -- a multistep manipulator for taking soil and rock samples, television and photographic cameras, devices for measuring hydrophysical parameters and a water-sampling system. Orientation under water is provided by a gyrocompass and circular scanning radar. Observations from the vehicles are conducted through three ports. Communications with the surface are accomplished through an underwater acoustic telephone.

Selecting the Region of Underwater Investigations

The main part of the complex geological-geophysical survey, the main purpose of which is to obtain a general idea of the geological structure of the lake

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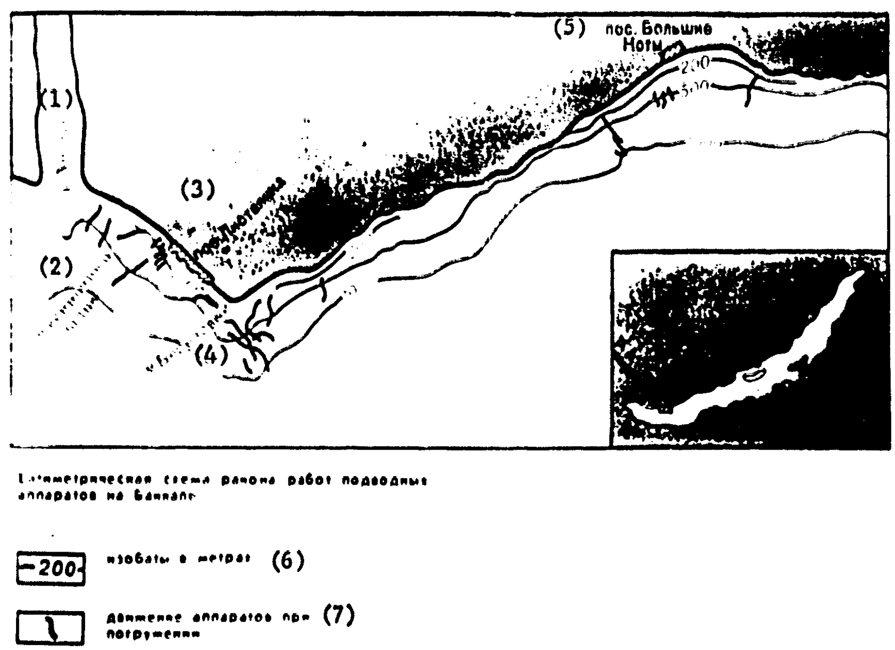
bottom and to select regions for detailed operations, was carried out in the southern basin of Lake Baykal.

Geophysical data confirmed that there is a sharp structural asymmetry of the Baykal trough. Its very steep northern slope is a magnificent scarp more than 1.3 km high, which changes to an almost flat channel by a sharp break. The southern, considerably more slanting slope consists of numerous submarine valleys, canyons and outcrops of coastal structures. Asymmetry is also manifested in the internal structure of the sedimentary mass which fills the trough. The mass of the sedimentary rock is deposited almost horizontally along the northern slope in a narrow band approximately 10-15 km wide. The sediments are crumpled into folds and are broken by tectonic disturbances within the southern side of the trough. The thickness of the sedimentary mass in the southern basin of Lake Baykal is not less than 2.1-2.4 km.



Bathymetric Chart of Region of Operations of Submersibles in Lake Baykal

KEY:

1. Angara River
2. Listvennichnyy Bay
3. Listvyanka
4. Cape Berezovyy
5. Bol'shiye Koty
6. isobaths in meters
7. movement of vehicles during submersion

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A magnetic survey with recording of the vertical and horizontal components of the geomagnetic field was first conducted in Lake Baykal. It should be emphasized that quiet, weakly negative magnetic anomalies, apparently occurring due to the fact that the crystalline foundation in the trough is submerged to a significant depth, were mainly recorded in Lake Baykal. However, individual intensive positive anomalies extending toward the slopes of the lake have been determined. They were recorded above the peak of Akademicheskiy Ridge, which separates the southern from the central basins of the lake. The sources of these anomalies are shallow, apparently directly under the sediments which overlap the strongly broken surface of the ridge and may be related to outcrops of the main rock -- basalts, now well-known on the Ushkan'iye Islands -- in the uplifted part of Akademicheskiy Ridge.

Analysis of geophysical materials showed that the most interesting object for study using submersibles is the northern submarine slope of the lake near Listvyanka and Bol'shiye Koty villages, where a detailed geological-geophysical survey was conducted prior to the beginning of underwater operations. This section is essentially devoid of sediments and one would expect that its relief is determined primarily by tectonic factors. According to results of echo sounding measurements, the average angle of the slope in this region varies from 25 to 40°. The slope is cut in places by canyons, part of which are continued by abovewater valleys. The slope is flattened out somewhat, apparently due to the fragmentary material carried out by small rivers, near the mouth of the Angara River in Listvennichnyy Bay. The slope forms a steep asymmetrical outcrop whose western side is considerably more slanting than the eastern side, near Cape Berezovyy. A significant number of dives in the vehicles was made in the region of this outcrop since a crushing zone was found in outcrops on shore, on the contiuation of which the magnetic anomaly was recorded in the lake.

A total of 42 dives of the submersibles, including 5 deeper than 1,000 m and approximately 20 to a depth from 500 to 1,000 m, was made during the expedition. In one of the dives, the crew of hydronauts consisting of A. M. Podrazhanskiy, A. M. Sagalevich and N. S. Reznikov reached the maximum depth of the southern Baykal basin -- 1,410 m. The plan of operations during the dive depended on the posed task. Thus, when the goal of the dive was to study the slope within a specific interval of depths, the vehicle was transported by a towboat to the given point and a free dive to the bottom was then begun. The "Pisces" then began to move upward along the slope, stopping to take television and photographic pictures and to take rock samples and for more detailed examination of the interesting sections of the slope. If a submarine canyon or valley had to be investigated, the vehicle moved perpendicular to the underwater structure, stopping for detailed visual observations and for taking samples.

According to echo-sounding data, the slope of the lake in the region of investigations is a steeply inclined smooth surface. However, observation from

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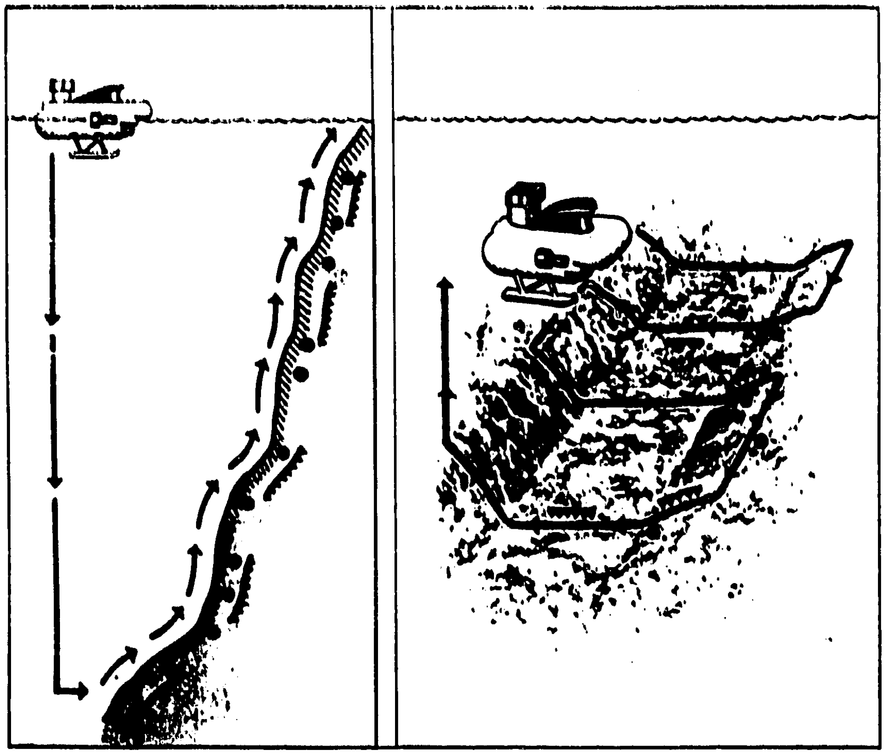

Схема работы «Пайсиза». Слева — движение аппарата при исследовании склона, справа — при исследовании подводного каньона.

направление движения аппарата (1)

места остановки (2)

участки получения видеозаписи (3)

Plan of Operations of "Pisces." On the left -- movement of the vehicle during examination of the slope; on the right -- during investigation of the submarine canyon

KEY:

1. direction of motion of vehicle
2. stopping points
3. sections of making video recording

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the vehicles made it possible to determine additional details.* It was determined that the slope has steps whose height reaches several tens of meters or more and whose width reaches 200-100 m at different levels and that the length at right angles to the slope exceeds 100 m. The steps are most clearly marked in the region of Cape Berezovyy and in Listvennichnyy Bay in the upper part of the slope. The steep sections of the slope separating the steps are usually devoid of sediments and are outcrops of bedrock intersected by cracks. The surfaces of the more sloping sections are inclined toward the axis of the trough and their slope is approximately one-half that of the separating scarps. These surfaces are covered with oozy deposits and pebbles, rock fragments and detritus are accumulated here. The steeper parts of the steps are excellent objects for study of the geological profile. Both vehicles approached the slope during the dive so that the geologist-observer had the opportunity to inspect the structural-textural features of the rock and their mineral composition in detail. This was difficult to do on fresh slopes, but in many cases the rock surface was covered with a reddish-brown crust of rust and samples had to then be taken in order to determine the type of rock. It turned out that the slope in the region of investigations is made up of rock related to the Precambrian basement of the Siberian Platform. Volcanogenic rock, widely distributed in the southwest and northeast of the Baykal rift zone, was not found anywhere.

The submarine canyons and valleys are yet another important aspect of separation of the submarine slope. Its surface usually changes in a sharp break into canyon walls which form an angle of 70-80° with the bottom of the canyons. The walls are frequently devoid of sediments and are outcrops of severely cracked bedrock. Detritus, rock fragments, rubble and sand were found on the bottoms of the canyons. All this and also the clearly marked erosion channels indicate that the canyons are natural canals along which the fragmentary material enters the deepwater basins. The underwater observers recorded numerous grooves in the bedrock, oriented along the maximum incline and formed more by fragments sliding downward on the slopes of Cape Berezovyy.

The morphology of the steps of the slope and submarine canyons indicates that they have an origin related to tectonic movements. The geologists-observers ascertained that the northern slope of the trough in the area of investigation was formed by a system of tectonic disturbances whose planes are parallel to its surface. The northern side of the trough seems to be separated into individual tectonic plates inclined in a direction from its axis. Observations from the "Pisces" vehicles confirm the primary tectonic origin of the canyons and their occurrence is apparently related to transverse cracks and ruptures which feather the main fault surrounding the trough from the west.

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*Geologists V. A. Abramov, Ye. A. Karabakov, V. V. Matveyenkov, Ye. G. Mirlin and V. A. Fialkov participated in the dives.

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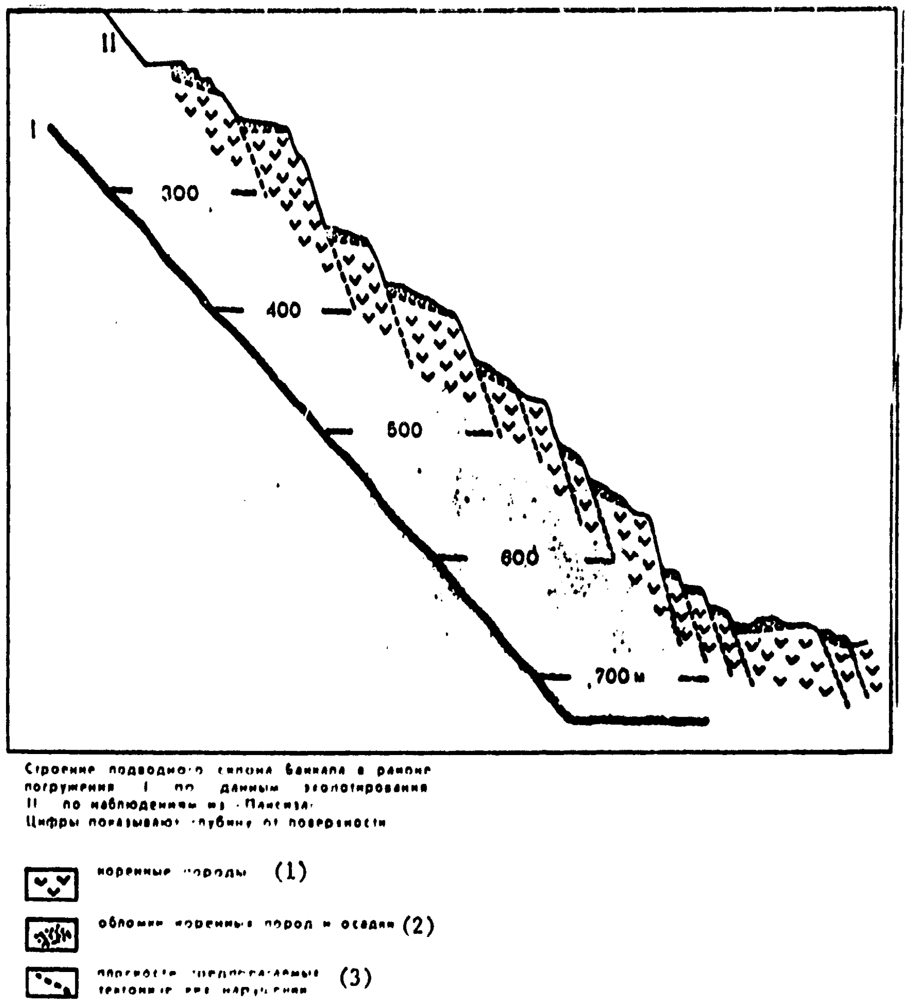

Structure of Underwater Slope of Lake Baykal in the Region of Diving: I -- according to echo-sounding data; II -- according to observations from the "Pisces"; the numbers indicate the depth from the surface

KEY:

1. bedrock
2. fragments of bedrock and sediments
3. planes of proposed tectonic disturbances

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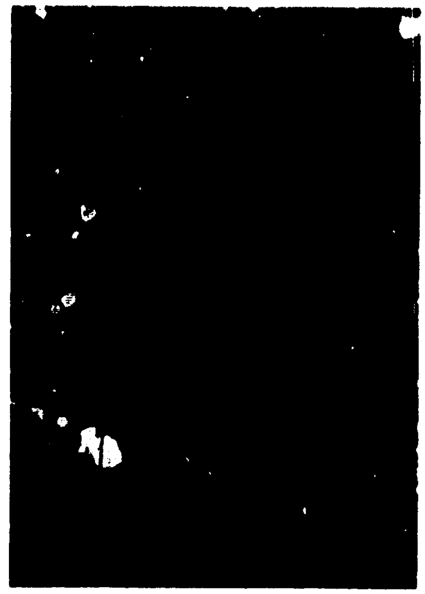
Outcrops of Bedrock Cut by a Crack at a Depth of 300 m



A Slanting Section of Slope Covered With Ooze Replaces the Steep Outcrop of Bedrock; Depth of 320 m

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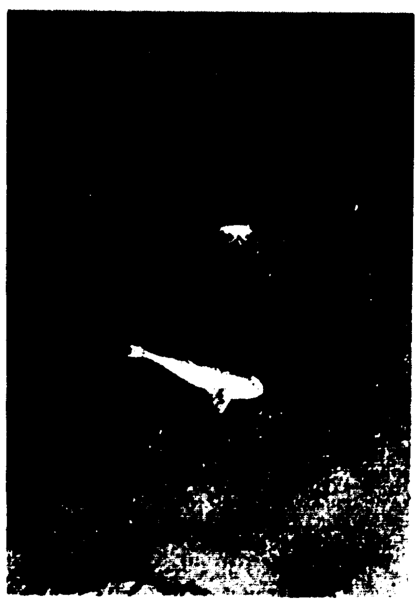
Will Lake Baykal Become an Ocean?

A condition for the occurrence of rift valleys and contiguous uplifts, regardless of where they are located -- on the continental or oceanic crust, is the presence of separations in the lithosphere -- the outer, brittle shell of the earth. Thus, continental rifts are probably formed in the following manner. The lithosphere is broken due to the effect of tensile stresses and a shear crack having an angle of inclination of approximately 60° is formed in it. Two blocks located on different sides of the crack are formed: one in its overhanging side and the other in the opposite under side. The overhanging block exerts somewhat greater pressure on its bottom than the average pressure of the vertical column of the lithosphere, while the horizontal block, cut by the sloping crack accordingly exerts less pressure. This causes a disturbance of gravitational equilibrium, which leads to intensive vertical movements in different directions. The section of crust which forms the overhanging block rises to the surface while the horizontal block, on the contrary, submerges. A deep trough and contiguous ridge are formed. This is the model for formation of asymmetrical grabens -- valleys with equal sides, proposed by F. Weniny-Meines in 1950.



Surface of Ooze at Depth of 1,410 m: goby (in foreground) and gammarus crayfish

Judging by available data, this model, at least in the first approximation, is suitable to explain the nature of the Baykal rift. Actually, there are numerous data of coastal geology which indicate a rise of the Primorskiy

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Ridge extending along the western coast of Lake Baykal during the Quaternary epoch. Wave-cut grottoes and coastal-lake boulders and pebbles are found at a height of 10 m or more above the water level in different regions on the western shore of the lake. In falling into the lake, the channels of many river valleys are seemingly jerked upward and are broken off in a steep outcrop. The outcrops, steps, longitudinal faults and steep cliffs are generally widely distributed elements of the relief of the western coast of Lake Baykal. As we have seen, the underwater relief of the western slope is also characterized by the presence of a large number of steps. In all probability the uplift of the Primorskiy Ridge, corresponding to surfacing of the section of crust on the horizontal side of the lithospheric crack, is accompanied by formation of tectonic plates and their collapse along the fractures of the main fault system which leads to formation of steps on the slope of the trough. On the other hand, the structure of the sediments and the morphology of the axial graben indicate that it was formed under conditions of stable prolonged downwarping. Thus, there are data on the intensive differential movements of the blocks which are predicted by the indicated model. The disturbance of the sedimentary mass on the eastern and southeastern sides of the rift trough are also completely explainable within the framework of this scheme since, according to it, the lithosphere is bent upon deep submersion of one of the blocks. Stresses occur at the point of this bend which are manifested in intensive tectonic disturbances of sediments.

If tensile stresses in the continental lithosphere continue, an additional crack sloping toward the first occurs in it. Similar vertical displacements of the sections of crust will also occur along the continuing crack, as a result of which a symmetrical graben with sunken axial block and uplifted limbs is formed. Subsequently, if the expansions increase, the thick continental lithosphere may be generally ruptured and the matter of the asthenosphere -- a layer which underlies the lithosphere and where the rock is in a partially molten state -- will begin to be introduced into the formed split. Since the lithospheric plates are moved in this case, the width of the fracture zone will increase and the edges of the continents will separate from each other, leaving a place for the newly formed oceanic crust. The progressive separation of the lithospheric plates will contribute to the fact that matter of the asthenosphere will continue to be introduced into the fracture crack. It hardens, crystallizes and changes to the solid matter of the lithosphere as the distance from the split increases. The thickness of the lithosphere will increase and its level will gradually subside since the density of the colder crystallized rock increases compared to the partially molten rock of the asthenosphere. The level will be maximum near the fracture where the lithosphere is theoretically generally absent and will then subside more and more in a direction away from it toward the edges of the separating continents. The matter of the asthenosphere hardens especially rapidly immediately in the zone of the split due to contact of the magma ejected to the surface with the ocean water. The cold and compact axial block formed in this case descends to the level of isostatic equilibrium which is maintained during motion of the plates. This is how a deep depression whose bottom consists of the youngest ejected rock of the

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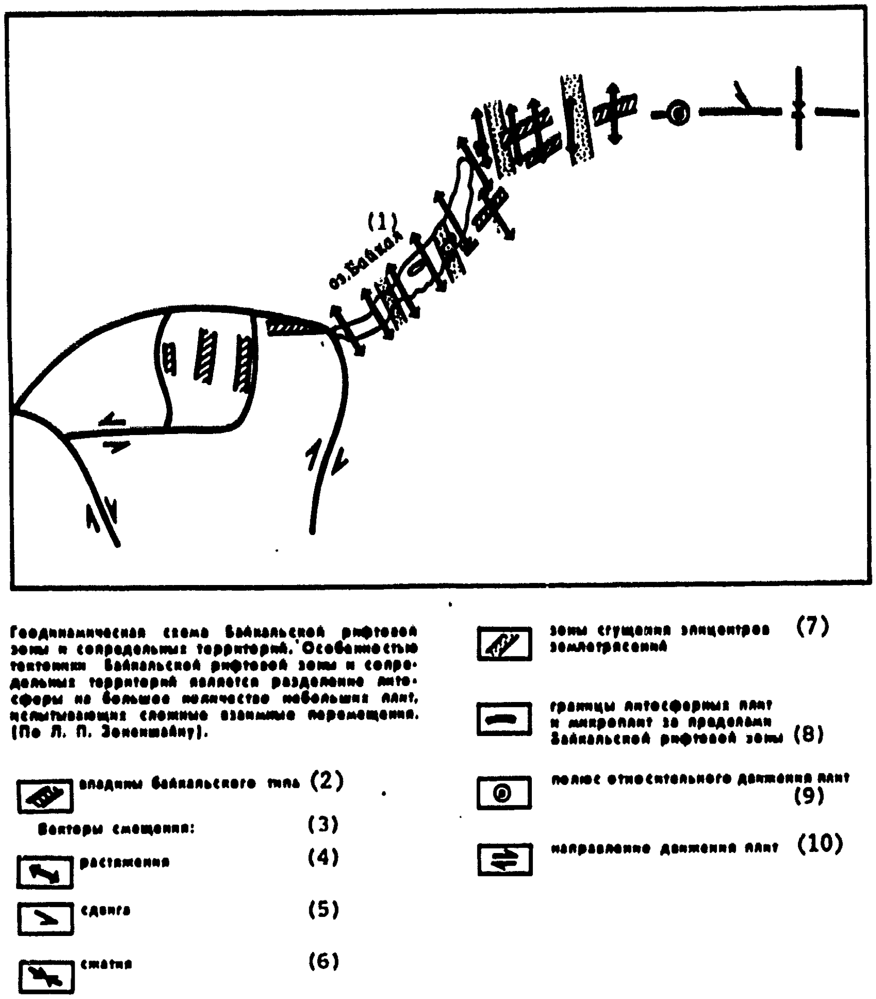
ocean bottom is formed on the background of the general symmetrical uplift of the bottom surface of a new ocean.



Geodynamic Chart of Baykal Rift Zone and Adjoining Areas. The characteristic feature of the tectonics of the Baykal rift zone and of the adjacent areas is separation of the lithosphere into a large number of small plates which experience complex mutual displacements (according to L. P. Zonenshayn)

(Key on following page)

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KEY:

1. Lake Baykal
2. Baykal type troughs
3. displacement vectors
4. tensile
5. shearing
6. compressive
7. zones of concentration of earthquake epicenters
8. boundaries of lithospheric plates and microplates beyond the Baykal rift zone
9. pull of relative motion of plates
10. direction of motion of plates

Such is the scheme which shows how an ocean with the main morphological structures of its bottom -- the mid-ocean ridges and the deep longitudinal depressions at their axis -- oceanic rifts -- may occur at the rotation of a continental rift. Detailed investigations carried out in the rifts by using towed bottom geophysical systems and submersibles showed that their slopes also have a clearly marked step structure. The surfaces of these steps are inclined in directions away from the axis. Formation of the steps is related to the fact that subsidence of the axial block occurs on a background of plate separation, as a result of which the lithosphere is separated into individual tectonic plates which are inclined in directions from the trough axis.

It is presently difficult to predict with complete certainty whether Baykal will go through the entire course of development from an asymmetrical continental graben, which it is at present, to a symmetrical oceanic rift located along the axis of the oceanic basin. It is not excluded that the tensile stresses in the lithosphere of Lake Baykal will attenuate and that the graben will cease to develop and will be filled in by sediments. Quite a few of these buried continental rifts, "unsuccessful pretenders" to the role of the oceans, are known. Another thing is important: on the basis of the new global tectonics, geologists can determine the deep cause-effect relationships of the evolution of various structures of the earth's surface.

The Nature of the Tensile Stresses of the Baykal Rift Zone

The presence of a narrow deep sediment-filled graben within Lake Baykal and steps on its slope are indirect features of the tensile stresses which predominate in a rift zone. These stresses are directly established from seismic materials. The belt of scattered seismicity intersects the Asiatic continent from the Pamirs to Stanovyy Ridge. Earthquake epicenters are localized within a relatively narrow band in the Baykal rift zone. Analysis of the orientation of the stresses at earthquake foci shows that tension oriented at right angles to its strike is prevalent in the Baykal zone. Compressive conditions are recorded farther to the east. Data on the orientation of stresses at earthquake foci were used by L. P. Zonenshayn et al. to calculate the pull of relative motion of lithospheric plates which are separated by the indicated seismic belt. It turned out that the pull is located to the east of the northern terminus of the Baykal trough. The lithospheric plates approach each other west of this point and move away from each other to the east of it, while the lines along which mutual motion occurs are fixed by concentration of earthquake epicenters.

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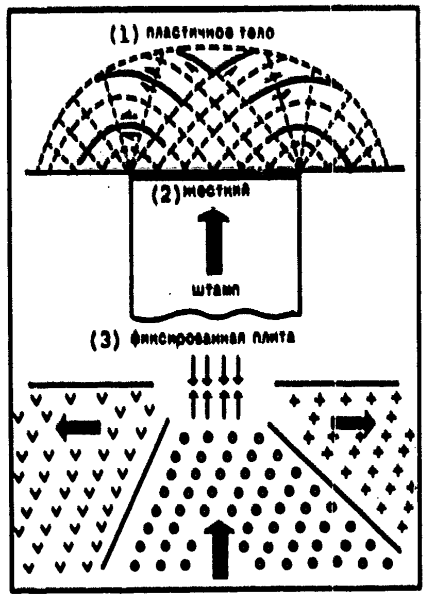

Схема, показывающая как единая монолитная литосферная плита может расколоться на ряд мелких плит под воздействием напряжений, возникающих при взаимодействии крупных плит и их столкновении. Вверху — модель внедрения жесткого штампа в пластичное тело, в котором возникают трещины и смещения, показанные пунктирными линиями и стрелками. Внизу — взаимодействие крупных плит (в плане). Скорости их взаимного раздвижения пропорциональны скорости плиты, играющей роль «штампа», и зависят от направлений границ между ними.

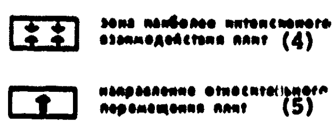

Diagram Showing How a Single Monolithic Lithospheric Plate May Be Broken Into a Number of Small Plates Due to the Effect of Stresses Occurring Upon Interaction of Large Plates and Collision of Them. Top -- model of introduction of "rigid die" into plastic body in which cracks and displacements occur, shown by the dashed lines and arrows; bottom -- interaction of large plates (in the foreground). The rates of their mutual separation are proportional to the rates of the plate which plays the role of the "die" and depend on the directions of the boundaries between them

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KEY:

1. plastic body
2. rigid die
3. fixed plate
4. zone of most intensive interaction of plates
5. direction of relative motion of plates

The question arises: are the sources of the horizontal tensile stresses in the Baykal rift the same processes as those on the boundaries of lithospheric plates in the oceans where the new oceanic crust is formed or are they caused by different, external factors?

The geodynamics of the Baykal rift zone, we feel, is explained best by the chart of P. Molnar and P. Tapon'ye, who analyzed the seismicity and tectonics of Central and Southern Asia. This analysis shows that the occurrence of large fracture zones of the crust at the location of the Baykal rift may be caused by the interaction of large lithospheric plates -- the Eurasian and Australian. The diagram of interaction of the plates agrees well with the "rigid die" model, in the role of which the Indostan Peninsula moving to the north and which exerts pressure on the Eurasian lithospheric plate, emerges. In this case stresses occur in the latter, due to the effect of which it is separated into a number of smaller plates (microplates) moving around different poles with respect to each other. Thus, for example, the Chinese platform together with the Mesozoic folded regions of the Transbaykal, the Pre-Amur region and the Sikhote-Alin', is shifted in an easterly direction away from northern Eurasia. The Baykal rift zone is precisely located along the lines of possible stresses and is the boundary of the microplates. Consequently, in the final analysis the formation of the Baykal rift is the result of pressure exerted by one large lithospheric plate on another.

Thus, the ideas of lithospheric plate tectonics permit one to tie together data of detailed observations within the active tectonic belt to the general geodynamic situation within the large region of our planet. In itself the possibility of investigating this relationship is a significant advantage of the new global tectonics which permits purposeful planning of future geological-geophysical research using new hardware.

The geological investigations conducted in Lake Baykal gave cause to check some global geotectonic hypotheses. But the geological investigations were not the only part of our program -- the "Pisces" vehicle made seven dives for biological purposes and we would like to discuss this at least briefly.

The Results of Biological Investigations

Observations of the behavior of freshwater animals were conducted for the first time at significant depths. Up to five specimens of the widely distributed Baykal oil-fish were located at the same time in the visual field of the observers. Attention is primarily drawn to the fact that the fish seem to hover in the water mass below the head. In this case their body constantly made wavy, pulsating motions. Near the bottom the Baykal oil-fish

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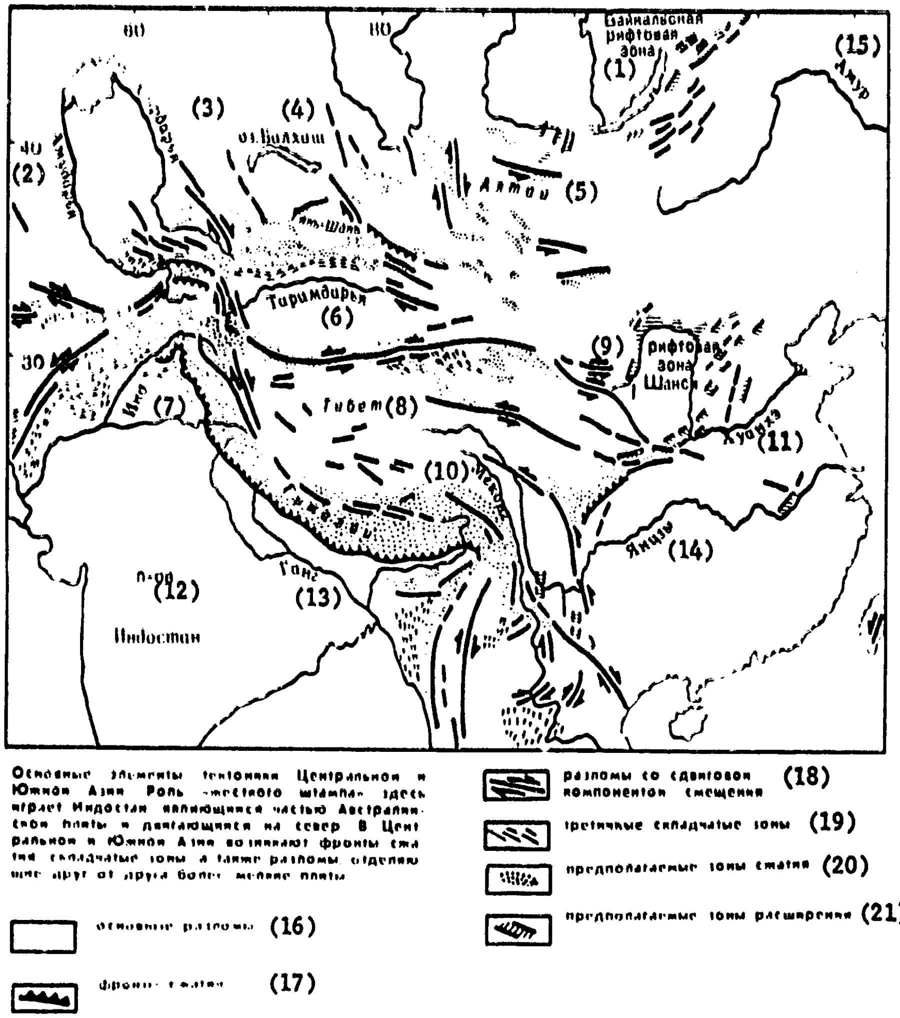

Main Elements of Tectonics of Central and Southern Asia. Indostan, which is part of the Australian plate and which moves to the north, plays the role of the "rigid die" here. Compression fronts, folded zones and also faults which separate smaller plates from each other occur in Central and Southern Asia

KEY:

1. Baykal rift zone
2. Amu Dar'ya River
3. Syr Dar'ya River
4. Lake Balkhash

(Key continued on following page)

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5. Altay
6. Tarim Dar'ya River
7. Indus River
8. Tibet
9. Shansi rift zone
10. Mekong River
11. Huang River
12. Indostan Peninsula
13. Ganges River
14. Yangtze River
15. Amur River
16. main faults
17. compression fronts
18. faults with shifting component of displacement
19. tertiary folded zones
20. proposed compression zones
21. proposed expansion zones

approached the accumulations of ooze from time to time, vigorously cut into it and, passing several centimeters under its surface, again floated upward. The biologist-observers* descriptively called these fish "plowmen of the Baykal bottom." The Baykal oil-fish usually did not react to the strong lights of the vehicles and were not afraid of the presence of the "Pisces." The numerous gobys also reacted calmly to the vehicles. There were cases when some of them stoved away on the instrument boom. The gobys moved away during attempts to collect them with a hand net. It was noted that the gobys dig themselves into the bottom or dig unique nests in the soft ooze.

The variation of the density of the organisms along the vertical was observed very clearly. Not only their number per unit volume but also the species composition varied. The most abundant fauna was noted in the bottom layer at depths above 400 m, especially on relatively slanting oozy slopes. Gammarus-crayfish predominate here and large specimens of Baykal oil-fish are found. The bottom surface is populated by bottom-dwelling crayfish, planaria and bottom gobys. Numerous colonies of sponges are found at the most diverse depths on the steep rocky slopes. It is typical that traces of the active vitality of bottom organisms in the form of numerous hillocks and funnels are recorded on the bottom at the maximum depth of the southern part of Lake Baykal.

The "Pisces" submersibles have now been installed on scientific research vessels of the USSR Academy of Sciences and are ready to begin operations to study the structure of the ocean bottom. The experience acquired during operations with the submersibles in Lake Baykal will be invaluable in the future investigations.

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*Biologists O. M. Kotova, V. N. Maksimov, G. N. Sidelev and N. S. Reznikov participated in the dives.

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PUBLICATIONS

DEVELOPMENT OF PROGRAM SOFTWARE FOR A SECTORAL AUTOMATED CONTROL SYSTEM

Moscow RAZRABOTKA PROGRAMMNOGO OBESPECHENIYA OTRASLEVOY ASU in Russian 1978 signed to press 9 Jan 78 pp 2, 3-5, 188-190, 199

[Annotation, introduction, appendix 1 and the table of contents from the book by O.V. Golovanov and V.V. Shkarupa, Statistika Publishers, Moscow, 23,000 copies, 199 pages]

[Text] Experience in the development and introduction of programming software for a sectoral automated control system for the chemical industry is described.

The characteristics of system problems are treated, as are the structure of the general programming software, questions of the design of data processing systems using the standard equipment of the operational systems of third generation computers. Particular attention is devoted to the use of a hierarchical data bank and remote processing. The development work was based on the IBM-360 computer, which is compatible with computers in the standardized series of electronic computers.

The book is intended for specialists engaged in the development of data processing technology in automated control systems, and can be useful to the workers of computer centers.

Introduction

The development of the program software for a sectoral ASU [automated control system] (OASU) is based on the wide-scale utilization of computers of the standardized computer series, and provides for the standardization of procedures for data processing and storage, as well as standard methods of operation in a "programmer - operator - computer" mode. The correct selection of the requisite hardware and software permits the creation of an economically favorable technology for data processing, oriented towards the support of functional programming subsystems and complexes of the OASU. In the book offered to the reader here, the primary attention is devoted to coding and programming processes, and to standard ways of utilizing standardized tools

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for the creation of the program software of data processing systems, the basic function of which is the derivation of reference, accounting and administrative information in the form of reference replies and interrogations. This goal is achieved by means of concentrating the data on the information carrires of computers and controlling the processing of the information by means of general and special program software, where the latter is based on the first, taking into account the standard procedures provided in it.

Special program software is created on the basis of an economic analysis of the system, as a result of which the framework of the future system is precisely outlined. An exhaustive and precise description of the system permits a reduction in the developmental cost of the special program software and a curtailment of the time required for its creation. The description of the system is based on an understanding of the requirements of the functional control subsystem and its economic essence. Taken into account are such factors as the composition and volume of the initial and final data, the characteristics of the document, the technical characteristics of the computer devices, the capabilities and limitations of the packages of applied programs, as well as the standards for the overall program software and other factors. If a system using remote processing facilities is developed, then the capabilities of the peripheral equipment are also considered (communications lines, terminals, control devices), and a provision is made for combining to the greatest extent possible the work of the individual users, who share the resources of the central facility. In designing large systems for integrated data processing, posed along with qualitatively new problems is the problem of increasing the labor productivity of the program software developers. The existence of packages of applied programs or programming systems creates only the appearance of a favorable situation, which disappears when a specific system is designed around them: months, and sometimes even years are required for the introduction and development of the latter. As the experience of a number of foreign firms has shown, outlays for system development where it is initially thoroughly worked out, proved to be twice as small as the outlays when a system is introduced concurrently with its development without a preliminary analysis of the system as a whole.

Developmental experience with the automated control system for the chemical industry (ASU-khim) using third generation computer equipment, which is described in this book, can prove to be of interest for many designers, since despite several specific features of this sector for the case of control automation at upper management levels in the hierarchy, the nature of the problems which arise is similar to the problems of automation in other sectors.

A unique feature of the present moment, which is typical of the majority of industrial sectors, consists in the fact that the design and introduction of systems is carried out simultaneously with the training of the specialists. A multiplicity of new people work on the design of the program software, and of them, only a few have experience in the automation of data processing on third generation computers. Regardless of the tasks in control automation that these specialists are called upon to perform, they are all

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faced with dealing with the elements of data processing systems, and for this reason, an effort is made in this book to combine the beginning working information dealing specifically with these questions. In using the hardware and software of third generation computers, it is essential to know the standards for data control, and the functions and rules for working with common programming software, high level programming languages, packages of applied programs and understand the characteristics of other tools oriented towards increasing design productivity and reducing the cost of problem solution.

Standard data processing systems, which incorporate a subsystem for data gathering, an automated bank, and subsystems for problem solution and displsying the results as integral components have become the basic elements in the design of program software. The structure of such systems is in accordance with the logic structure of the control system, and for this reason, their overall design is based on an analysis of the operation of the facility being automated and the data processing functions in it, and are treated in Chapter 1. In accordance with the analysis, requirements are established for the data processing system, in particular, an enumeration of the specific output documents with their printout composition and periodicity indicated. These requirements determine the structure and composition of the data base. The economically acceptable data processing technology, including the initial data input, the updating of mutually related sets of data (basis) and information output as a result of the solution of specific problems, is established through the use of standard program software and hardware.

The project planning for the data processing technology based on standard operational system equipment is described in Chapter 2, where the operations of generating and maintaining files, and feeding out information are treated; series processing using merger algorithms and sorting routines is analyzed. The specific features of direct data access are demonstrated using the example of index-series organization, and the conditions leading to the creation of an integrated data bank are analyzed, while the specific example of data processing technology in the OASU subsystem using a package of applied programs, which organizes communications of the "product composition" type, is also analyzed.

The technological fundamentals of working with an automated data bank are treated in Chapter 3 using the example of a hierarchical information control system, and an example is given of the structure of a data bank for information and reference problems of the ministry. In Chapter 4, which is devoted to the fundamentals of modern remote information processing technology, a system of data input from a display keyboard is described, as are the technology for data processing using a remote processing system, the logic of elementary input operations, and data correction and examination.

Appendix 1.

The Equipment Complement of the Sectoral Computer Center

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The basis of the equipment complex of the sectoral computer center of the Ministry of the Chemical Industry is composed of "Minsk-22" (4 units) and "Minsk-32" (2 units) second generation computers, and one third generation computer, a 360-50 manufactured by the IBM company. The computers are located in three places: the IBM-360-50 and two "Minsk-22" at the main center, one "Minsk-32" computer at Tula, two "Minsk-22" computers and one "Minsk-32" at Kiev, as well as an IBM-3780 terminal station connected to the IBM-360-50 via a separate telephone channel. Installed in the room of the ministry are three IBM-3275 information displays, which are connected to the IBM-360-50 via separate telephone communications channels, as well as teletypes for receiving information from the enterprises and punched card/tape machines.

The following equipment is included in the complement of the IBM-360-50 (see the figure): a central processor with a one megabyte high speed memory, equipped with one multiplex and three selector channels and an IBM-1052 control board typewriter; the IBM-2314 magnetic disk memories (9 disc assemblies with a capacity of 29 Mbytes each) with an IBM-2319 control block, which is connected to the selector channel; IBM-3420 model 3 magnetic tape memories with two IBM-3803 control blocks, connected to two selector channels. The control blocks have a switcher which provides for the simultaneous operation of two tape transport mechanisms in any combination.

There are seven tape transport mechanisms in all, of which six operate with a record density of 1,600 bytes/inch (64 pulses per mm) and one mechanism can operate with a record density of both 1,600 bytes/inch and 800 bytes/inch (32 pulses per mm); two IBM-2540 punched card input-output devices, three IBM-1403 line-at-a-time printers; an IBM-2703 line communications control block, which includes one synchronous and one start-stop line base. Connected to this block are the following: an IBM-3780 terminal in Kiev, CRT information displays in the ministry and in the center itself, as well as five IBM-2741 terminals and telegraph channels.

We shall give a brief description of the devices cited here. The model 50 series 360 electronic computer is an intermediate model (in terms of the technical characteristics) from a series of computers which are compatible with each other at both the programming level and at the level of peripherals interfacing. It operates with binary, decimal and alphabetic information. Numbers can be represented both with a floating and a fixed decimal point. The minimal addressable information element is the byte, consisting of eight binary digits. The length of a computer word is equal to 4 bytes or 32 bits. It is also possible to work with double length words.

The direct access memory takes the form of magnetic discs, which include eight 2314-B1 disc drives, and an IBM-2319 control block. There is a ninth standby disc drive. Interchangeable packets of type 2316 discs are used in the 2314-B1 unit, where these discs include 11 plates with 20 working surfaces. The capacity of a packet is 29.177 Mbytes. The working surface of a disc has 203 tracks with a capacity of 7,294 bytes.

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The IBM-3420 tape transport simultaneously records with nine pairs of heads, thus forming nine information tracks. Nine digits comprise one byte with a parity check digit. Nonreturn-to-zero recording is used to record with a density of up to 800 pulses per inch, and the phase potential method is used to record with a density of 1,600 pulses per inch. The memories are connected to two IBM-3803 control units, each of which in turn is coupled to different selector channels.

The information output is accomplished by means of a 1403 line-at-a-time printer. This unit prints at a rate of up to 1,100 lines/min (with a special set of symbols), covering a whole line at once, which contains 132 symbols.

The IBM-2540 unit consists of two devices: a reader and a perforator. The punched cards are fed out wide side first from the reader magazine at a rate of 1,000 cards/min through two sets of reader brushes into one of three receptacle pockets. Each pocket holds 3,100 punched cards. The cards flow from the magazine of the perforator through the perforation point, the read point and go to one of three receptacle pockets at a rate of up to 300 cards/min. The central receiving pocket is used by both devices, which operate independently of each other. The unit is connected to a multiplex channel.

The control board typewriter (an IBM-1052) permits printout on paper and the feeding of information into the computer from the keyboard. This unit is usually employed for printing out brief messages for the operator at a rate of 14.8 characters per minute. There are 89 print symbols on the keyboard of the IBM-1052, and of them, 26 are line letters and 63 are special symbols.

The IBM-2703 is intended for organizing the interchange between the central processor and the terminals connected through communications lines. The unit is connected to the multiplex channel and provides for operation in a start-stop mode at a maximum speed of up to 600 bits/sec, and in a synchronous mode at a maximum rate of up to 4,800 bits/sec.

The IBM-3780 is the most productive terminal station, which provides for reading punched cards at a rate of up to 600/min and prints out messages at a rate of 300 - 425 lines/min. The unit operates in two modes: independently and in an interchange mode through a communications line. In the latter case, the IBM-3870 either feeds the punched cards through the reader, or receives the data which is to be printed out on the station printer. In the independent mode, the data are read by the reader from the punched cards, are printed out, but are not transmitted to the communications line. The IBM-3780 operates in a semiduplex mode via switched or segregated communications channels. The data transmission rate in the communications equipment and the modems is up to 1,200 bits/sec. Operation is possible via segregated channels in a duplex mode, increasing the transmission rate up to 2,400 bits/sec.

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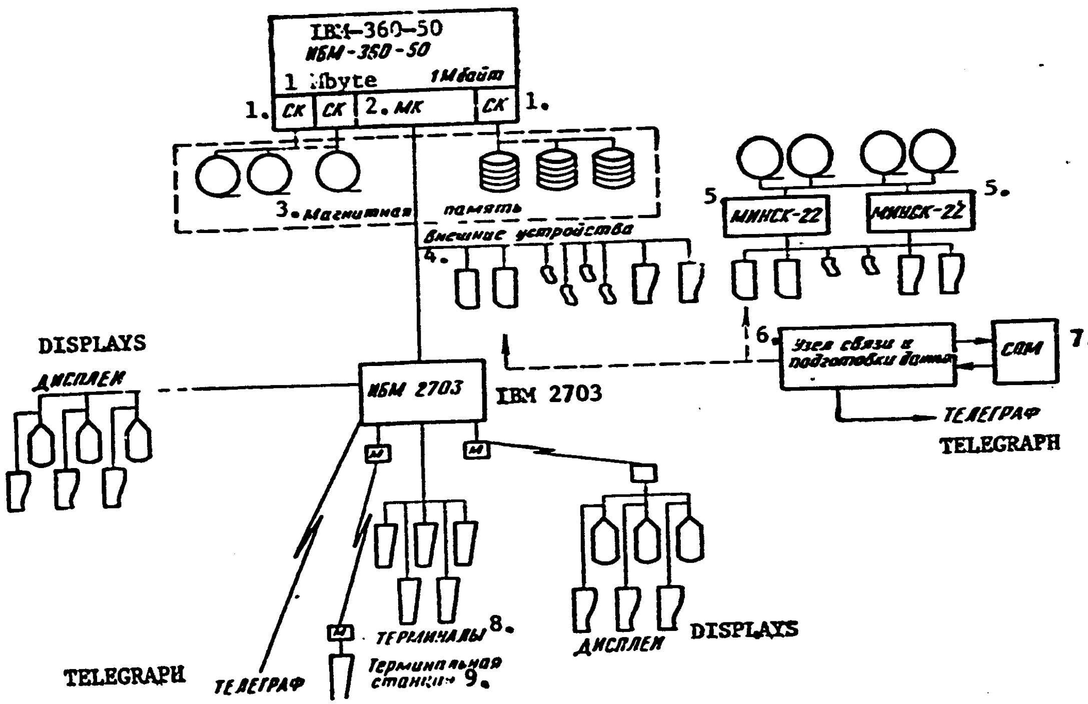

The equipment base of the sectoral computer center

Key:
1. SK [Selector channel];
2. MK [Multiplex channel];
3. Magnetic memory;
4. Peripherals;
5. MINSK-22;
6. Data preparation and communications unit;
7. SPM [Punched card/perforated tape];
8. Terminals;
9. Terminal station.

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The IBM-3275 is a display, which was described in Section 4.2. An IBM-3284 printer is connected to the IBM-3275 display for data printout, where the print rate of the former is 40 characters/sec.

Information exchange is accomplished at a rate of 1,200 bauds.

The IBM-2741 terminal is a typewriter, and can operate in a time sharing mode or can be used as a standard typewriter.

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PUBLICATIONS

PROTECTING COMMUNICATIONS FACILITIES FROM HAZARDOUS AND INTERFERING EFFECTS

Moscow ZASHCHITA SOORUZHENIY SVYAZI OT OPASNYKH I MESHAYUSHCHIKH VLIYANIY in Russian 1978 signed to press 7 Dec 77 pp 2, 286-288

[Annotation and table of contents from book by Mikhail Ivanovich Mikhaylov, Leonid Davydovich Razumov and Stanislav Aleksandrovich Sokolov, Izdatel'stvo Svyaz', 288 pages, 10,000 copies]

[Text] An account is given of key questions relating to protecting communications facilities from the hazardous and interfering effect of LEP's [electrotransmission lines], electric railroad contact networks and lightning discharges. The values are given, of permissible hazardous and interfering voltage and current in communication circuits. A technique is given for estimating the hazardous and interfering influences of high-voltage lines on communications facilities. A discussion is given of the theory of the protective effect of various pieces of equipment and devices used in lines and in communications equipment.

This book is intended for engineers and technicians in communications planning, construction and operating organizations.

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PUBLICATIONS

VERBAL COMMUNICATION IN ARTIFICIAL ATMOSPHERES

Moscow RECHEVAYA SVYAZ' V ISKUSSTVENNYKH ATMOSFERAKH in Russian 1978 signed to press 5 Apr 78 pp 2, 144

[Annotation and table of contents from book by Boris Ivanovich Petlenko and Leonid Sergeyevich Butyrskiy, Izdatel'stvo Svyaz', 144 pages]

[Text] Questions are discussed, relating to the properties of speech signals under conditions of a modified gas medium and to technical problems in restoring intelligibility of speech under conditions of deepwater immersion and space flights requiring the use of special breathing mixtures.

This book is intended for specialists in the field of communications engineering, acoustical engineers, linguists, pyschologists and physiologists involved in research on speech signals.

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PUBLICATIONS

UDC 621.372.8

OPTICAL COMMUNICATIONS WAVEGUIDES

Moscow VOLNOVODY OPTICHESKOY SVYAZI in Russian 1978 signed to press 30 Jan 78 pp 2, 3, 168

[Annotation, table of contents and preface to the book by I.I. Teumin, Svyaz' Publishers, Moscow, 3,700 copies, 168 pages]

[Text] The elements of the theory and engineering of optical band waveguides, intended for use in optical communications systems, are presented. Questions of signal propagation, waveguide excitation and the principles of optical cable design are treated.

The book is intended for scientific workers engaged in design work on and the application of optical communications devices.

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Preface

One of the promising trends in the development of information transmission systems is the use of the optical band of electromagnetic waves. Beginning in the middle of the 1960's, publications of the results of work done in this field appeared in an extremely wide range of periodical literature. Special attention was devoted in this literature to the development of the theory and a description of devices for closed optical communications lines using special waveguides. Almost all of the published materials on optical waveguides were not combined to the necessary extent with a common approach, in particular, from the viewpoints of the design work on multichannel optical communications systems. A considerable amount of the work is of a theoretical nature, and its results cannot always be used directly in an engineering plan. For this reason, the need has arisen for a systematized treatment of the questions relating to the theoretical elements of optical waveguides, the transmission of signals through them, and their utilization for optical communications.

An attempt is made in this monograph to systematically present the issues indicated above to the extent necessary for engineering designs, at least for the initial stages, as well as for the further deeper study of literature in this field. For purposes of effectively utilizing the volume of the book, intermediate conclusions (with the exception of original ones) have been omitted in discussing individual questions.

Soviet researchers have made a large and serious contribution to the development of theoretical and practical questions relating to dielectric waveguides in general, and to optical band waveguides in particular. Thus, a substantial contribution to the general theory of dielectric waveguides has been made by B.Z. Katsenelenbaum, V.F. Vzyatyshev and N.A. Semenov, and in the field of optical band waveguides by V.V. Shevchenko, A.S. Belanov and Yu.N. Kazantsev. A number of separate theoretical questions, as well as important experimental developmental work in this field, are reflected in the works of A.M. Prokhorov, Ye.M. Dianov, D.K. Satarov, V.B. Veynberg, M.Ye. Zhabotinskiy, A.A. Dyachenko and other researchers.

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PUBLICATIONS

TESTS (THEORY, DESIGN AND APPLICATION)

Novosibirsk TESTY (TEORIYA, POSTROYENIYE, PRIMENENIYE) in Russian 1978 signed to press 27 Feb 78 pp 2, 188-189

[Annotation and table of contents from book by Nikolay Andreyevich Solov'yev, Izdatel'stvo Nauka, Sibirskoye Otdeleniye, 192 pages, 3,500 copies]

[Text] A presentation is made of the key concepts of one of the new divisions of cybernetics--the theory of tests. Methods of designing tests are given, and a discussion is presented of their application for troubleshooting in electrical circuits and for solving certain problems in identifying objects.

This book can be useful to specialists interested in the applied aspects of mathematical cybernetics.

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